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Specification and Drawings, as originally filed, with Application for Patent Serial No: **2,426,874**, on April 25, 2003, by **REGENT TECHNOLOGIES LTD.**, assignee of Mike Claerhout, for "Apparatus and Method for Thermal Deburring of Slotted Well Liners".

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ABSTRACT OF THE DISCLOSURE

A method and apparatus for removing burrs from inside slotted metal liners exposes the burrs to a high-intensity gas flame that effectively oxidizes or vaporizes the burrs, without inducing undesirable temperature levels in the parent material. This is accomplished using a torch head assembly having multiple gas torch nozzles disposed radially around the circumferential perimeter of the torch head, such that when the torch head is passed through the interior of a slotted liner, the flames are directed toward the interior surface of the liner. Auxiliary oxygen is introduced at the nozzle outlets, resulting in a large increase in flame velocity and intensity, which in turn increase the flame temperature. The auxiliary oxygen may be introduced through annular passages surrounding the nozzles, such that the auxiliary oxygen effectively forms a cylindrical curtain surrounding the flame at each nozzle.

APPARATUS AND METHOD FOR THERMAL DEBURRING OF SLOTTED WELL LINERS

FIELD OF THE INVENTION

The present invention relates to apparatus and methods for removing burrs from internal surfaces of tubular goods, and in particular for removing burrs from internal surfaces of slotted pipe.

BACKGROUND OF THE INVENTION

In the production of oil or gas from an subsurface formation, steel liner pipes with multiple longitudinal slots ("slotted liners") are commonly installed in both vertical and horizontal wells to allow oil or gas present in the formation to enter the wells, whereupon the oil or gas can then be pumped or otherwise lifted to the surface for processing. The slots must be narrow enough to prevent significant amounts of formation materials from entering and clogging up the well and associated equipment such as pumps. For wells installed in formations containing fine-grained materials, liner slot width may need to be as narrow as 1.0 millimeters (0.04 inches) or less. The slots must be long enough and numerous enough to allow for effective flow into the liner, without reducing the liner's structural strength below safe levels. The liner's structural strength (especially its flexural strength) is particularly important for horizontal wells, in which the liner must retain

sufficient strength to be bent through transition sections between vertical and horizontal wellbores without fracture or excessive plastic deformation.

The slots are of any convenient length, but they are typically in the range of 75 mm to 100 mm (3 to 4 inches) long. They are usually arrayed at uniform spacing about the circumference of the pipe, at radial intervals as low as 5 degrees. They are commonly cut into the liner sidewall using narrow circular slitting blades. One known method uses a "gang mill" fitted with multiple slitting blades radially oriented on planes passing through the longitudinal axis of the liner. As the liner is moved longitudinally relative to the gang mill, the blades are deployed so as to cut slots of desired length through the liner sidewall.

Rather than making perfectly clean cuts, the slitting blades tend to leave jagged burrs or "wickers" where the slots intercept the interior surface of the liner. These burrs and wickers are undesirable for a variety of reasons, so the production of slotted liners typically includes steps to remove them, but known methods of doing so are not entirely satisfactory. One common method is to run a device commonly called a "stinger" through the slotted liner. The stinger has multiple rotating blades disposed such that they will essentially scrape the interior perimeter of the liner as the stinger passes through. The intent is that the rotating blades will cut off the wickers, which can then be removed from the liner by compressed air or other means.

However, this method has proved to be only partially effective, because the scraping blades tend to bend the burrs and wickers and push them back across or into the slots, causing a direct reduction in the open slot area available for passage of oil into the liner. This problem is particularly evident for slot widths of 0.04 inches and less. The effective slot area tends to become further reduced when the liner is placed in service, because foreign materials entering the slots build up on the bent-back wickers, causing the slots to become partially or totally plugged.

Other mechanical methods, such as honing or burnishing, have been used in an attempt to polish the wickers down. However, these methods have similar drawbacks, in that they tend to simply brush some or all of the wicker metal back into the slots.

When using known deburring methods having such significant drawbacks, it may be necessary to allow for slot plugging by providing a greater amount of slotting than might otherwise be required. It has been observed that slot plugging can reduce the effective permeability of a slotted liner by as much as 40% to 60%, so in order to obtain a desired permeability, liners may have to have a slotted area up to or more than twice as large as the area theoretically required for a given application. Such extra slotting obviously increases liner fabrication cost. It also decreases the structural strength of the liner, possibly entailing the use of liners with greater wall thickness, thus increasing the total cost of the slotted liner even further.

In addition to the foregoing problems, wickers or any other material left inside slotted liners can damage or interfere with expensive down-hole tools used in well-servicing operations.

A possible alternative approach to wicker and burr removal would be thermal deburring; i.e., exposing the wickers and burrs to a high-temperature flame. It is well known that burrs of steel or other materials can be burned off and effectively vaporized if subjected to a sufficiently hot flame. This would in theory facilitate very effective removal of burrs from a slotted liner, as it would be fairly simple to remove the residue from the process (i.e., oxides) using compressed air, high-pressure water blasting, or other conventional means.

For the type of steel commonly used for slotted liners, effective use of this method would require heating the burrs to temperatures in the range of 6000° F. At the same time, though, care would have to be taken to ensure that the temperature of the main body of the liner does not become excessive, in order to prevent undesirable metallurgical changes in the parent metal. This would not be overly difficult if the high-temperature flame could be effectively focused or concentrated on the burrs and not on the main body of the liner, because the much larger mass of the liner (i.e., compared to the mass of the burrs) would allow efficient dissipation of the heat applied to the burrs through conduction, without excessive temperature build-up in the parent material. However, it is virtually impossible to direct a flame toward burrs inside a steel liner without exposing the main body of the liner to the flame. Furthermore, the inventors have observed that when conventional flame sources such as acetylene torches are used in an attempt to heat burrs inside a slotted liner to temperatures

sufficient to achieve vaporization, the flame must dwell upon the burrs for so long that excessive localized heating of the parent metal is unavoidable. The prior art appears to disclose no solution to this problem.

For the foregoing reasons, there is a need for wicker-removal and deburring apparatus and methods that can remove burrs and wickers from slotted metal liners with substantially greater effectiveness than known apparatus and methods. In particular, there is a need for such apparatus and methods that can remove burrs and wickers by exposure to an oxidizing flame, without raising the temperature of the adjacent parent metal so high as to cause metallurgical changes or other undesirable effects. The present invention is directed to these needs.

BRIEF SUMMARY OF THE INVENTION

In general terms, the present invention is a method and apparatus **10** whereby burrs inside a slotted metal liner may be exposed to a gas flame so as to effectively oxidize or vaporize the burrs, without inducing undesirable temperature levels in the parent material. This is accomplished using a torch head **20** having multiple gas torch nozzles **50** disposed radially around the circumferential perimeter of the torch head **20**, such that when the torch head **20** is passed through the interior of a slotted liner, the flames are directed toward the interior surface of the liner. A substantially stoichiometrically-balanced fuel mixture (i.e., combustion gas and oxidizing gas) is delivered to the nozzles **50**, so as to produce substantially neutral-burning flames at the nozzles **50**. It has been

determined, through testing, that the temperature of a neutral-burning flame will increase considerably in the presence of oxygen. In accordance with the present invention, therefore, auxiliary oxygen is introduced near the nozzle outlets, resulting in a large increase in flame velocity and intensity, which in turn increase the flame temperature. In the preferred embodiment, the auxiliary oxygen is introduced through annular passages **44** surrounding the nozzles **50**, such that the auxiliary oxygen effectively forms a curtain surrounding the flame at each nozzle **50**.

The temperature of the torch flames produced according to the present invention is thus considerably higher than it would be without auxiliary oxygen. It has been found that when the torch head **20**, having a suitable number of torch nozzles **50**, is passed through a slotted liner at an appropriate rate of travel, the flame intensity is sufficient to vaporize a very high percentage of burrs and wickers from the liner, without excessive temperature rise in the parent metal. The appropriate torch head travel speed will depend on a variety of factors, including liner diameter and wall thickness, feed pressures of the fuel mixture components and the auxiliary oxygen, the number of nozzles **50** on the torch head **20**, and the distance from the nozzle outlets to the inner surface of the liner. As only one representative example, it has been found that a travel speed in the range of 4.0 to 4.5 feet per minute is effective for deburring a nominal 7-inch diameter steel liner (7.75" O.D., 6.35 I.D.) using a torch head **20** having 48 radially-disposed torch nozzles **50** burning a MAPP gas mixture fed at approximately 20 psi (pounds per square inch), with auxiliary oxygen fed at approximately 50 psi, and with the radial distance between the nozzle outlets and the inner surface of the liner being approximately 0.5 inches.

The fuel mixture used in the torch head 20 may be any suitable mixture of combustion gas and oxidizing gas, including a mixture of acetylene and oxygen. In the preferred embodiment, however, the fuel mixture will comprise MAPP gas (i.e., methylacetylene-propadiene) and oxygen. While acetylene produces a higher flame temperature, it has been found that a MAPP gas flame is more stable than an acetylene flame. Propane or natural gas, which also produce suitably stable flames, could also be used, but their heating values are lower than for MAPP gas, making the latter more desirable to optimize burr removal rates.

The torch nozzles 50 may be of any suitable construction having central longitudinal fuel passages 54 for conveying the fuel mixture from a fuel plenum 30. In one embodiment, the torch nozzles 50 are conventional "MIG tips"; i.e., wire-feeder tips used in the metal-inert gas welding process. It has been found that acceleration of the fuel mixture as it exits the fuel passages 54 of the nozzles 55 facilitates establishment of a stable, neutral flame, by inducing a certain amount of backpressure and increasing the flame velocity. Accordingly, in one embodiment of the apparatus of the invention, the fuel passages 54 of the nozzles 55 have a narrowing or constriction near the external ends thereof, so as to accelerate the fuel mixture as it exits the nozzles 55.

In the preferred embodiment, the torch head 20 will also have a flame shield 70, which may be provided in the form of a collar or flange mounted aft of the torch nozzles 50 and extending radially outward from the torch head 20, but stopping just short of the inner surface of the liner such that it does not impede passage of the torch head 20 through the liner. The flame shield 70 serves

two primary functions, the first of which is to shield from the flames those portions of the liner which the torch head **20** has already passed by, thus further minimizing the liner temperature. The second function or effect of the flame shield is to concentrate the torch flames in a region immediately adjacent to the nozzles **50**, by preventing the flames from deflecting back over the region previously exposed to the flames.

In the preferred embodiment, the apparatus **10** of the invention will include centralizer means **60**, for ensuring that the longitudinal axis A of the torch head **20** is substantially aligned with the axis of the liner through which the torch head **20** passes when the apparatus is in use, thus ensuring that all of the torch nozzles **50** are approximately equidistant from the inner cylindrical surface of the liner, so as to facilitate substantially consistent heat transfer from the nozzles **50** to the liner. As particularly illustrated in Figure 3, the centralizer means **60** may include a plurality of rollers **62** disposed radially about the perimeter of the torch carrier body **12**, each roller **62** being mounted to a bracket **64** hingingly connected to the of the torch carrier body **12**, and each bracket **64** having biasing means (such as a spring) for urging the rollers **62** radially outward so as to rotate against the inner surface of the liner as the torch head **20** passes through.

Just as the liner needs to be protected from excessive heat build-up, the temperature of the torch head **20** also must be kept within an acceptable range. For this purpose, the apparatus **10** of the invention may also include means for cooling the torch head **20**. Although the torch head **20** may be effectively cooled using a gaseous coolant such as air, in the preferred embodiment the torch head

20 is cooled by circulation of a liquid coolant (which could comprise water or ethylene glycol) through one or more coolant chambers 24 within the torch head 20.

In the preferred embodiment of apparatus and method of the invention, the torch head 20 is movable through the liner being deburred. In alternative embodiments, however, the liner may be moved over a stationary torch head 20.

It will be readily appreciated by those skilled in the art that various modifications of the present invention may be devised without departing from the essential concept of the invention, and all such modifications are intended to be included in the scope of the claims appended hereto.

In this patent document, the word "comprising" is used in its non-limiting sense to mean that items following that word are included, but items not specifically mentioned are not excluded. A reference to an element by the indefinite article "a" does not exclude the possibility that more than one of the element is present, unless the context clearly requires that there be only one such element.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a perspective view of the torch head and torch carrier body of one embodiment of the invention.

Figure 2 is a close-up view showing the torch head, heat shield, and centralizer means of one embodiment of the invention.

Figure 3 is a close-up view of the centralizer means of one embodiment of the invention.

Figure 4 is a cross-section of the torch head of an embodiment of the invention in which the torch nozzles are oriented substantially perpendicularly relative to the axis of the torch head.

Figure 5 is a cross-section of the torch head of an embodiment of the invention in which the torch nozzles are oriented with a forward cant.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A deburring apparatus **10**, for removing burrs from interior surfaces of a metal pipe, said apparatus comprising:

(a) a torch carrier body 12 having a front end 14 and a rear end 16;

(b) a torch head **20** connected to the torch carrier body **23** at the front end **24** thereof, said torch head **20** having a longitudinal axis **A** and a circumferential lateral surface **22**, and said torch head **20** defining:

b.1 a fuel plenum **30**, for receiving a fuel mixture comprising a combustion gas and a primary oxidizing gas;

b.2 an auxiliary plenum **32**, for receiving and conveying an auxiliary oxidizing gas from a source of auxiliary oxidizing gas;

b.3 a plurality of fuel channels **34**, each having an outer end **34a** and an inner end **34b**, each fuel channel **34** at its said inner end being in fluid communication with the fuel plenum **30**; and

b.4 a plurality of elongate nozzle ports **40**, each said nozzle port **40** having an inner surface **42** and extending inward from the circumferential lateral surface **22** of the torch head **20**, and each nozzle port **40** being in fluid communication with the auxiliary plenum **32**; and

(c) a plurality of torch nozzles **50**, each said nozzle **50** having an outer surface **52**, an inner end **50a**, and an outer end **50b**; and each nozzle **50** having a fuel passage **54** extending through the nozzle **50** from said inner end **50a** to said outer end **50b**;

wherein:

(d) each nozzle **50** may be installed within, and substantially coaxially with, a corresponding one of the nozzle ports **40**, each nozzle **50** having a cross-sectional dimension smaller than that of its corresponding nozzle port **40**, such that an annulus **44** is formed between the outer surface **52** of the nozzle **50** and the inner surface **42** of the nozzle port **40**;

(e) the outer end **50a** of each nozzle **50** extends close to or beyond the circumferential surface **22** of the torch head **20**;

(f) the inner end **50a** of each nozzle **50** is sealingly engageable with a corresponding one of the fuel channels **34**, such that the outer end of the fuel passage **54** of each nozzle **50** is in fluid communication with the fuel plenum **32**; and

(g) each said annulus **44** is in fluid communication with the auxiliary plenum **32**, and intercepts the circumferential surface **22** of the torch head **20**.

2. The deburring apparatus of Claim 1, further comprising centralizer means **60**, for substantially aligning the longitudinal axis **A** of the torch head **20** with the longitudinal axis of the pipe.

3. The deburring apparatus of Claim 21 wherein the centralizer means **60** comprises a plurality of rollers **62** disposed circumferentially around the torch carrier body **12**, each roller **62** being rotatably mounted to a roller bracket **64** hingingly mounted to the torch carrier body **12**,, and each roller bracket **64** having biasing means for urging the associated roller **62** radially outward.

4. The deburring apparatus of Claim 1, further comprising a flame shield.

5. The deburring apparatus of Claim 1, further comprising fuel mixture control means, for regulating the flowing pressure of the fuel mixture.

6. The deburring apparatus of Claim 1, further comprising auxiliary oxidizing gas control means, for regulating the flowing pressure of the auxiliary oxidizing gas.

7. The deburring apparatus of Claim 1 wherein the fuel passage of at least one torch nozzle has a constriction so as to accelerate the fuel mixture as it exits the nozzle.

8. The deburring apparatus of Claim 1, further comprising torch head cooling means.

9. The deburring apparatus of Claim 8 wherein the torch head cooling means uses a circulating coolant fluid, and wherein the torch head defines one or more coolant circulation chambers.

10. The deburring apparatus of Claim 9 wherein the coolant fluid comprises a liquid coolant.

11. The deburring apparatus of Claim 10 wherein the liquid coolant comprises water.

12. The deburring apparatus of Claim 9 wherein the coolant fluid comprises a coolant gas.

13. The deburring apparatus of Claim 12 wherein the coolant gas comprises air.

14. The deburring apparatus of Claim 1 wherein the combustion gas comprises MAPP gas, and the primary oxidizing gas comprises oxygen.

15. The deburring apparatus of Claim 1 wherein the auxiliary oxidizing gas comprises oxygen.

16. The deburring apparatus of Claim 1, further comprising motive means for moving the torch head longitudinally through the pipe.

17. The deburring apparatus of Claim 1, further comprising motive means for moving the pipe longitudinally while the torch head remains stationary, such that the torch head effectively moves through the pipe.

18. The deburring apparatus of Claim 16 or Claim 17, further comprising means for controlling the torch head's rate of travel relative to pipe.

19. The deburring apparatus of Claim 1, further comprising means for monitoring the temperature of the pipe in the vicinity of the torch nozzles.

20. The deburring apparatus of Claim 1 wherein the nozzle fuel passages are oriented substantially perpendicularly to the longitudinal axis of the torch head.

21. The deburring apparatus of Claim 1 wherein the fuel channel of at least one nozzle is canted toward the front end of the torch head.

22. The deburring apparatus of Claim 1 wherein the at least one nozzle is a MIG tip.

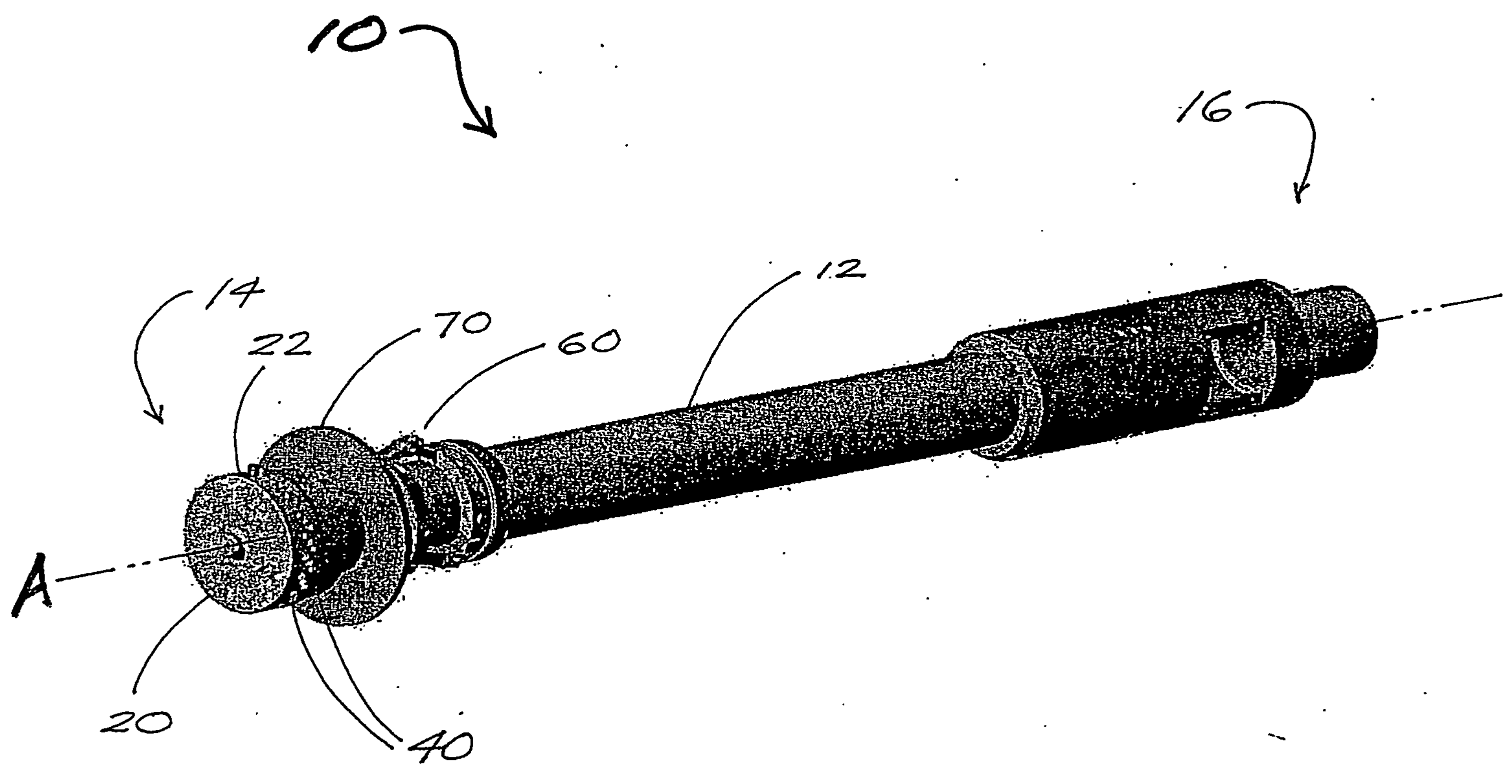

FIGURE 1

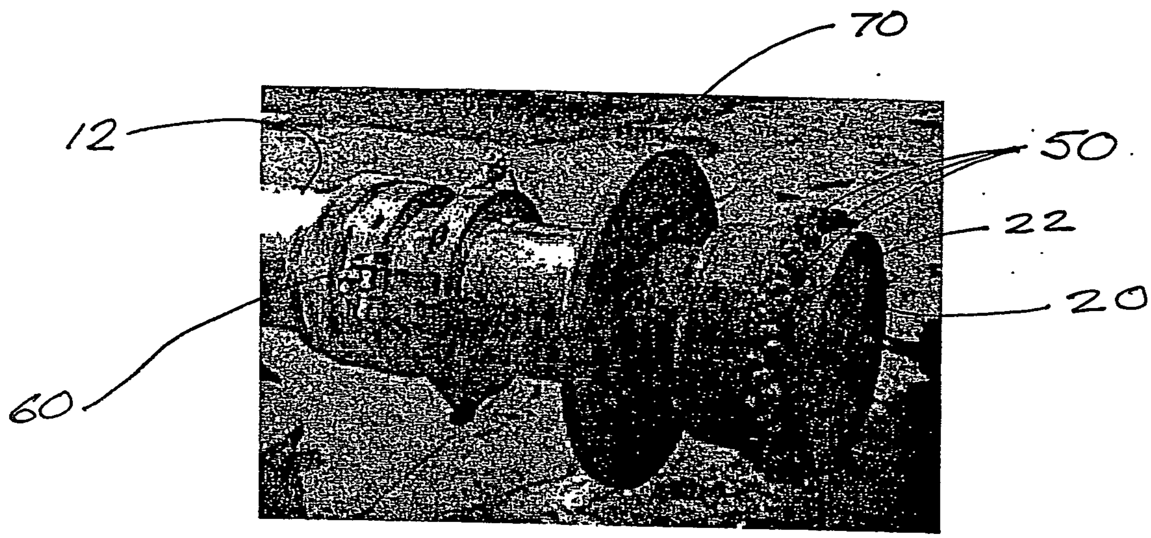

FIGURE 2

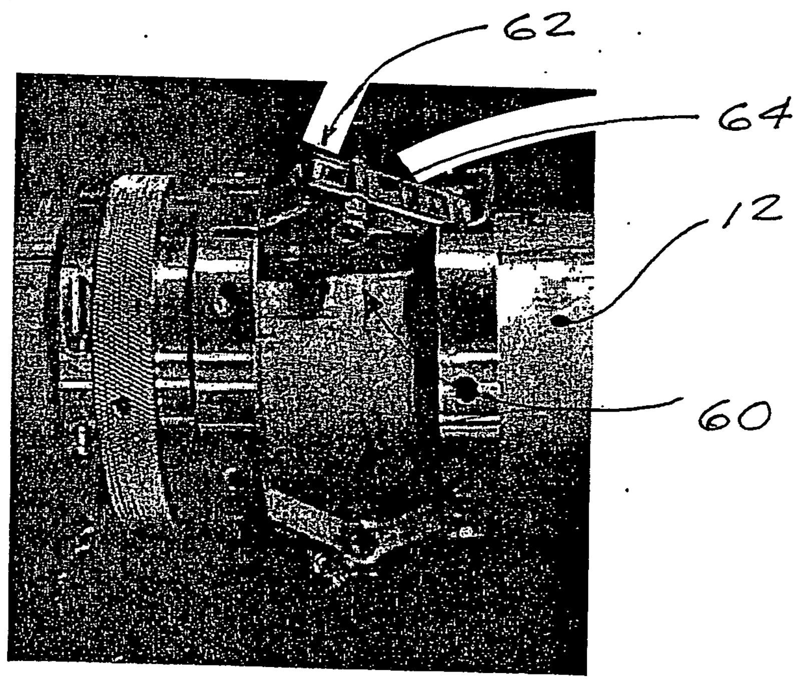

FIGURE 3

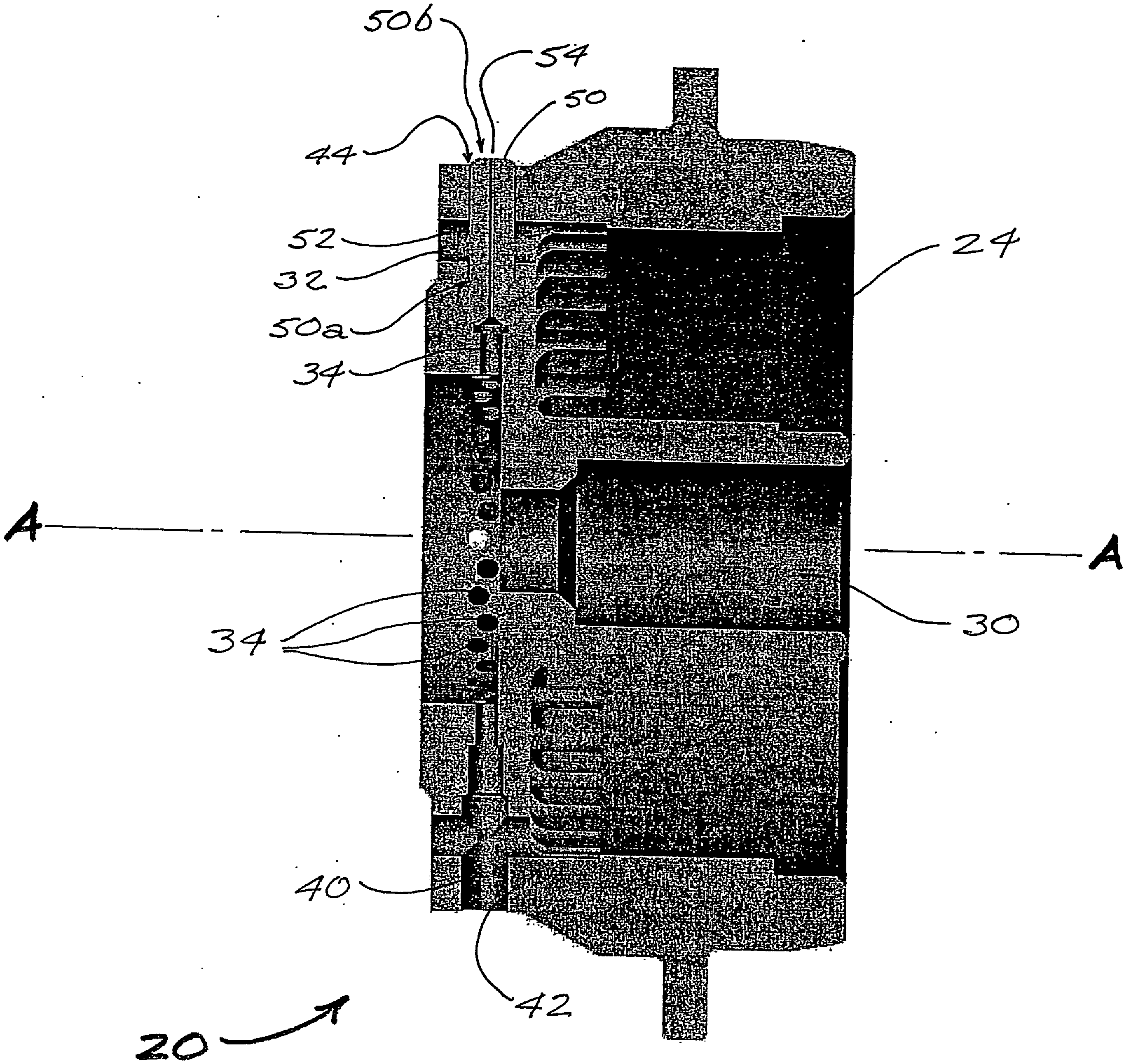

FIGURE 4

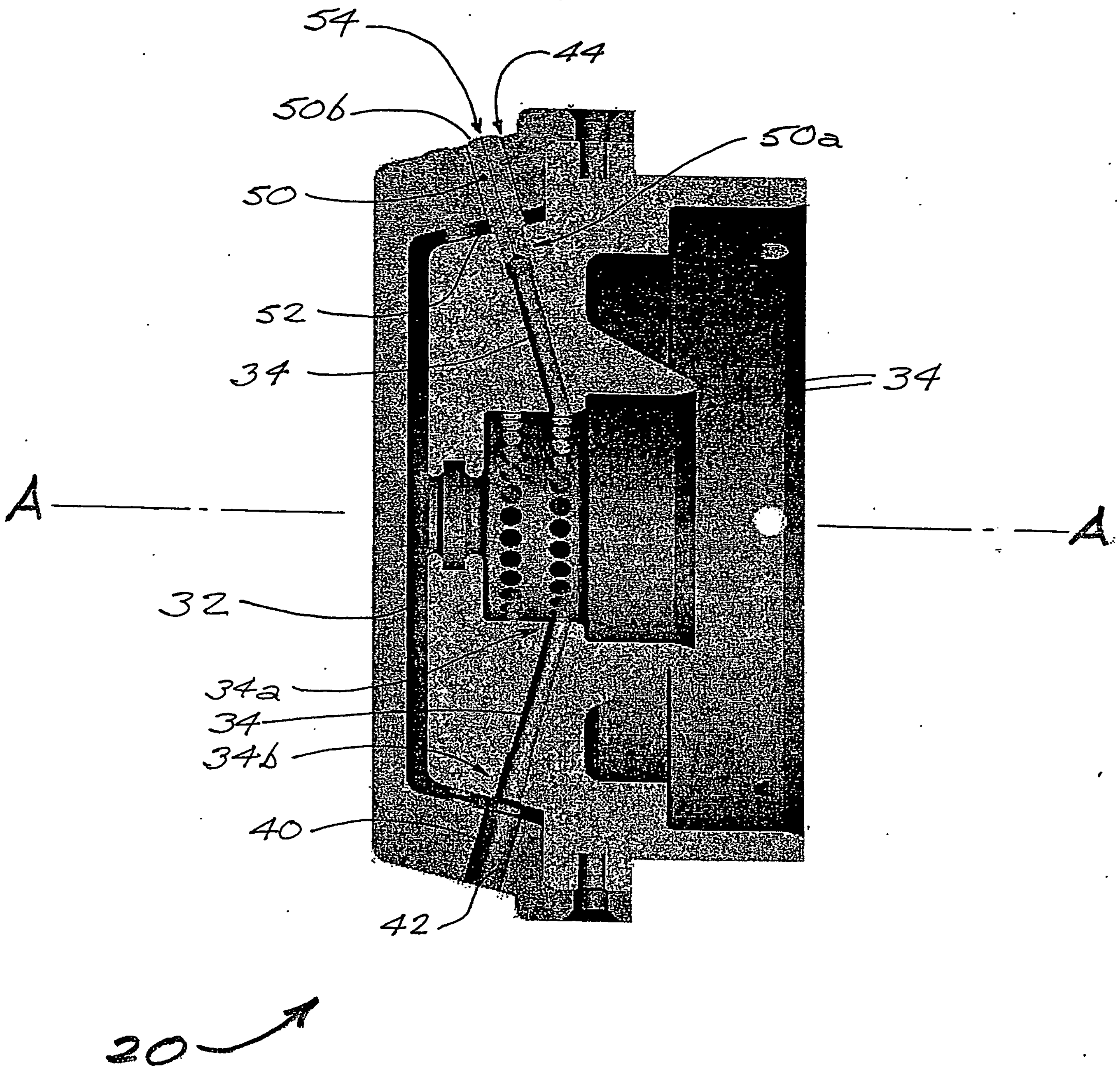

FIGURE 5

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